UNITED STATES
DEPARTMENT OF AGRICULTURE
DEPARTMENT CIRCULAR 404
Washington, D. C. December, 1926

CONCENTRATED SOUR SKIM MILK[1]

L. A. ROGERS
Senior Bacteriologist

WM. T. JOHNSON, JR.
Associate Bacteriologist

H. G. ALBERY
Junior Dairy Manufacturing Specialist, Bureau of Dairy Industry

CONTENTS

	Page		Page
Purpose and method of the work	1	Marketing	5
Fermenting the milk	2	Special combinations	6
Concentrating the sour milk	4		

PURPOSE AND METHOD OF THE WORK

As the cost of producing milk increases, the problem of utilizing dairy by-products becomes more acute. Each year it is more necessary to utilize to the fullest extent all the solids of milk.

Under the present conditions, two important economic losses in the production of milk are (1) the waste of skim milk at seasons of surplus milk supply, and (2) the difficulty of disposing profitably of the vast quantity of skim milk produced in the manufacture of butter.

The city milk dealer attempts so to balance the milk purchased with that sold that there will be no shortage and no surplus. This is obviously difficult, and the normal variations both in production and consumption result at times in an excess of milk which can not be disposed of through the usual channels. The fat of this surplus milk is easily utilized as cream or butter, but the skim milk is often not used. Since this surplus occurs only intermittently and is extremely variable in quantity, it can not be used in making a product for which a steady market is necessary unless the product can be

[1] The process described in this circular is covered by the following: ROGERS, L. A. PROCESS OF MAKING A FOOD PRODUCT FROM SKIM MILK. (U. S. Patent No. 1,477,153.) U. S. Patent Office, Off. Gaz. 317: 415. 1923. This patent has been dedicated to the public and may be used without restriction.

19877°—26

stored at not too great an expense; nor is it feasible to employ for intermittent operation any process requiring expensive equipment involving a correspondingly high overhead charge or an especially skilled personnel.

Of the skim milk produced in the manufacture of butter, only a minor part is actually wasted, as nearly all of it is fed to farm animals. Because of the difficulty of adjusting the requirements of these animals to the uneven production of milk, much of the skim milk is fed inefficiently. For this reason most farmers would prefer to sell it at the creamery if a fair price could be obtained. Moreover, many creameries are obliged to convert the skim milk and buttermilk into a salable product in order to meet the competition of city milk trade, condenseries, or other agencies using the whole milk.

In many sections where special attention is given to raising poultry or hogs, there is a constant demand for milk products which can not be supplied locally. An economic gain would result if the surplus skim milk of the city milk plant and the creamery could be converted into a form in which it could be preserved and transported to these sections having a shortage of milk for feeding.

This has been done successfully in the case of buttermilk by concentrating it, usually in a vacuum pan, to a point at which the natural acidity of the product is high enough to prevent the growth of bacteria and yeasts. This makes a pasty product with about 28 per cent milk solids. It is made on an extensive scale, especially in the large creameries, and is highly valued as a poultry and hog feed.

The casein of buttermilk is in the form of a finely divided precipitate which can be heated with little tendency to form large aggregates. On the other hand, skim milk soured by the ordinary lactic streptococci has an acidity at, or a little on the acid side of, the isoelectric point of casein, and when heated to the temperature of the vacuum pan with a vacuum of 24 to 26 inches, it gathers into large masses and burns on the coils so that it can not be handled by the usual process. This tendency can be overcome in part by thoroughly breaking up the curd by churning or homogenizing, but it is very difficult or impossible to carry the concentration sufficiently low to bring the final acidity to a point at which the product will be preserved.

Both of these difficulties can be overcome by using special cultures by which the acidity of the unconcentrated milk is brought above 1.7 per cent calculated as lactic acid. This high acidity has a solvent action on the precipitated casein, which is increased as the acid is concentrated by the evaporation of water in the pan. With an acidity of at least 1.7 per cent no difficulty is experienced in the pan, and a product with a very smooth texture is obtained.

Active cultures of the bulgaricus type may be used for this purpose; but a mixed culture of a bulgaricus and a mycoderm, which will develop an acidity of 1.7 to 2 per cent in 18 hours, has been found especially useful.

FERMENTING THE MILK

In order that an active culture free from contamination may be available every day, a small "mother culture" should be carried.

This is made by steaming or holding in boiling water for a half hour or more a small quantity of milk; for instance, a quart Mason jar two-thirds full. When this has cooled to 100° to 110° F., it may be inoculated with the culture which is usually in milk in a test tube. To keep the "mother starter" at the proper temperature it is essential that an incubator be provided, preferably one with electric heat and control. If electricity is not available, an oil-heated egg incubator will answer. Cultures of the bulgaricus type grow most rapidly at temperatures a little above 100° F.

In order to minimize the danger of contamination by yeasts which are able to grow in the acid milk, the temperature of the incubator should be above the growth limits of these organisms. This will be not less than 105° F.; and to be within the growth limits of bulgaricus, not above 110° F.

Milk inoculated with a good culture late in the afternoon should be curdled with a high acidity the following morning. After a small quantity, about 1 teaspoonful, is used to inoculate another freshly sterilized jar of milk, this "mother starter" is ready to inoculate the starter which is to be added to the milk to be soured and concentrated.

This starter should be prepared in sufficient quantity to make from 1 to 2 per cent of the milk to be soured. Two per cent is recommended. This is prepared by heating skim milk to 180° F., or higher, for at least a half hour with thorough agitation to insure adequate heating of all the milk. This is done most conveniently in the starter cans made for this purpose. When the milk has cooled to 115° F. the "mother starter" should be added and the stirrer run for a few minutes. The temperature should be held as closely as possible at 100° to 110° F., and the inoculation timed so that the starter is still in the actively growing stage when it is added to the milk. An old starter—that is, one that has been curdled for a number of hours—will be slow in starting the fermentation.

The milk to be concentrated should be Pasteurized either in a continuous machine at 170° to 180° F. or by the holding method. A high temperature of Pasteurization is desirable, not only to destroy bacteria which might cause abnormal fermentations during the ripening, but also because a high Pasteurization temperature tends to make a smoother texture in the finished product. With the holding method this temperature may be 150° to 160° for 30 minutes.

The vat for ripening should be covered and should have, if possible, a coil for heating, cooling, and stirring. Glass-lined tanks are satisfactory. Cypress vats, if properly constructed and cared for, have been found to give good results. The high acid in conjunction with the relatively high temperature has a tendency to discolor and corrode tinned vats.

When the Pasteurized milk is cooled to 115° F., 2 per cent of starter should be added slowly with the stirrer running to insure an even distribution. If the milk is not stirred a portion of it will be curdled by the acid, and lumps will form which will injure the quality of the finished product.

The ripening conditions should be adjusted to allow a drop in temperature of not more than 10° in 18 hours. At the end of this

period the acidity of the milk should be between 1.7 and 2 per cent lactic acid—that is, 10 cubic centimeters of the milk should require 18.8 to 24.4 cubic centimeters of n/10 sodium hydroxide to give a pink color when phenolphthalein is used as an indicator.

CONCENTRATING THE SOUR MILK

The first step is to break up the curd as thoroughly as possible with the ordinary coils or agitators. The milk is then drawn into the pan at the temperature at which it comes from the vat. Forewarming is unnecessary and tends to harden the lumps of curd, making a rough texture in the finished product. Forewarming with direct steam causes the milk to lump so that it can not be condensed. If the acidity of the milk before concentrating is high enough there is no difficulty from lumping or burning on the coils.

It is essential that the acidity be developed high enough to insure the keeping quality of the finished product. This will vary somewhat with the concentration of the solids, the contamination, and the conditions under which it is held in storage, but 5 per cent acidity should be considered the lowest limit. A smoother texture and a more stable product is obtained if the acidity is about 6 per cent.

Because of the heavy body of the finished product the degree of concentration can not be determined by the usual Baumé method. However, three ways of determining the concentration are available. One is the picnometer method in which a small flask which can be completely filled is weighed on a balance accurate to one-tenth of a gram and this weight compared with that of the same flask filled in the same way with the milk before concentration. The concentration can be easily calculated from the relation of these two weights. The weight which this definite volume of concentrated milk should have will soon be established, and it will be necessary to continue the evaporation only until this weight is reached. A convenient metal flask with attachment for quick filling has been described by F. R. Evans.[2] The objection to this method is the difficulty of filling the flask quickly without forming air bubbles which will obviously affect the weight.

A second method is the titrating of the acidity, which increases very nearly in direct relation to the concentration. Thus, if the skim milk contains 9.2 per cent solids and a final product with 28 per cent solids is required, it will be necessary to concentrate to approximately one-third of the volume. Consequently, if the milk has an acidity of 1.9 per cent, the evaporation should be continued until a titration shows an acidity of three times 1.9 per cent, or 5.7 per cent.

The third method is the determination of the refractive index, which has been suggested for condensed milk, and which is the most satisfactory method for estimating concentration.[3] The refractive index varies directly as the concentration of the soluble solids, and the relation of these constituents to the total solids is nearly constant.

---

[2] EVANS, F. R. DEVICE FOR RAPID DETERMINATION OF THE SPECIFIC GRAVITY OF CONDENSED MILK. Jour. Dairy Sci. 8: 37–38, illus. 1925.

[3] RICE, F. E., and MISCALL, J. SWEETENED CONDENSED MILK. IV. A REFRACTOMETRIC METHOD FOR DETERMINING TOTAL SOLIDS. Jour. Dairy Sci. 9: 140–152. 1926.

The refractometer required is rather expensive, but its operation is simple and a determination can be made in a very short time. A little clear serum is obtained by pressing a small sample of the milk in a cloth with a fine mesh. A few drops of this serum is placed between the plates of the refractometer and the refractive index read. When this is known for a batch of milk with the required amount of total solids, it is then only necessary to continue the evaporation until the refractive index coincides with that of the standard batch.

The concentration should be carried to about 28 per cent solids. At this point it flows freely from the pan and has a thick, pasty consistency when cold. It is run from the pan direct to the container without cooling.

The composition of a concentrated product made from skim milk containing 9.2 per cent total solids would be approximately as follows:

	Per cent		Per cent
Fat	0.17	Ash	2.13
Casein	8.06	Lactic acid	6.08
Albumin	2.13	Water	72.00
Lactose	9.43		

Oak or fir barrels with a capacity of about 500 pounds are the most satisfactory containers. They may be secured secondhand, but should be tight and coated with paraffin or sodium silicate. It is especially necessary that the barrels be tight, as even a small leak will cause an appreciable loss and may create an air space in which mold will develop. Caution should be observed in storing leaky barrels on a cement floor as the acid whey actively attacks the cement.

Secondhand butter tubs, well paraffined, will serve for local trade but are not satisfactory for shipment. For the customer who wants small lots, tin cans with friction tops are sometimes used; but they rust rapidly and are not entirely satisfactory.

When properly made, concentrated sour milk will keep indefinitely without appreciable change. If the acidity is above 5 per cent, there will be no abnormal fermentations even at summer temperatures, except that when the surface is exposed to the air, molds will develop. It does not freeze at ordinary winter temperatures.

MARKETING

The market price for this product has varied from 3 cents a pound at the factory when sold in car lots to 4 cents in small packages. No difficulty has been experienced in disposing of large quantities, either to poultrymen and hog raisers in the vicinity of the plant or to jobbers who specialize in poultry feeds.

The cost of making is dependent on many variable factors and is difficult to estimate. One company on the basis of an annual production of 700,000 pounds estimates the cost of manufacture at 1½ cents per pound.

With ordinary skim milk and with a milk-solids content of 28 per cent in the finished product, a yield of 33 pounds per hundred pounds of skim milk should be obtained. Estimating the cost of manufacture at 1½ cents per pound and the package at three-fourths of a

cent per pound, a price of 3 cents per pound at the factory would net approximately 25 cents per hundred for skim milk.

If 3½ cents per pound is obtained, the return would be 41 cents per hundred, and at 4 cents the return would be 58 cents. As a means of disposing of surplus skim milk this product has certain advantages. It is a staple product with an established market. It can be made at any season of the year and stored to supply a uniform demand, or it can be sold to jobbers whenever a sufficient quantity for shipment has accumulated.

SPECIAL COMBINATIONS

It is now clearly established that milk sugar (lactose) has a very definite function in controlling digestive disturbances due to infections of the lower intestines. This has been shown by Rettger[4] in investigations on white bacillary diarrhea of chickens, and more recently Beach[5] has demonstrated that milk sugar is a valuable agent in combating coccidiosis. His experiments indicate that feeding chicks a dry mash containing 20 parts of lactose included as lactose or as skim-milk powder, which contains about 50 per cent lactose, materially reduced the losses among chickens heavily infected with coccidiosis.

The milk-sugar content of concentrated sour milk may be increased by combining skim milk with whey, which contains about 5 per cent lactose. In this way the feed value of whey, when it is available in conjunction with skim milk, may be utilized, and the value of the product for poultry feeding considerably increased.

The whey and skim milk should not be mixed until they have been Pasteurized and soured, after which they may be drawn into the pan and concentrated together. A culture that will give 2 per cent acidity in milk will give only about 1 per cent in whey. This will be offset by the greater concentration which will be required to bring the proteins to the right point for satisfactory texture. Since the water content is lower, the solution of acid is as strong as when a higher acid is obtained with a lower total-solids content. If equal volumes of whey, with a total-solids content of 6.25 per cent, and skim milk containing 9.2 per cent total solids are mixed and concentrated in the ratio of 3.9 to 1, a finished product will be obtained with a composition approximately as follows:

	Per cent		Per cent
Fat	0.20	Ash	2.54
Casein	5.30	Acid	5.85
Albumin	2.96	Water	69.69
Lactose	13.46		

The texture and general appearance is in no way inferior to that made from skim milk alone.

---

[4] RETTGER, L. F., KIRKPATRICK, W. F., and CARD, L. E. CHICKENS: MILK FEEDING AND ITS INFLUENCE ON GROWTH AND MORTALITY. COMPARATIVE STUDY OF THE VALUE OF SWEET AND SOUR MILK. Storrs (Conn.), Agr. Expt. Sta. Bul. 80. 1915.

[5] BEACH, J. R. THE EFFECT OF FEEDING BACILLUS ACIDOPHILUS, LACTOSE, DRY SKIM MILK, OR WHOLE MILK ON THE HYDROGEN ION CONCENTRATION OF THE CONTENTS OF THE CECA OF CHICKENS. Hilgardia 1: 145–166. 1925.

——— and DAVIS, D. E. THE INFLUENCE OF FEEDING LACTOSE OR DRY SKIM MILK ON ARTIFICIAL INFECTION OF CHICKS WITH EIMERIA AVIUM. Hilgardia 1: 167–181. 1925.

The sugar content, which is a little less than 50 per cent of the total-solids content, corresponds very closely to that of skim-milk powder. It seems probable that this product could be substituted for skim-milk powder in a ration designed to check coccidiosis in chickens.

One hundred pounds of equal parts whey and skim milk would give a yield of about 25 pounds of finished product. Although this would reduce the returns from skim milk, it would make a satisfactory market for whey. The cost of manufacture would be increased by the added cost of evaporating the water from the whey.

ORGANIZATION OF THE UNITED STATES DEPARTMENT OF AGRICULTURE

December 15, 1926

Secretary of Agriculture	W. M. JARDINE.
Assistant Secretary	R. W. DUNLAP.
Director of Scientific Work	A. F. WOODS.
Director of Regulatory Work	WALTER G. CAMPBELL.
Director of Extension Work	C. W. WARBURTON.
Director of Information	NELSON ANTRIM CRAWFORD.
Director of Personnel and Business Administration	W. W. STOCKBERGER.
Solicitor	R. W. WILLIAMS.
Weather Bureau	CHARLES F. MARVIN, *Chief.*
Bureau of Agricultural Economics	LLOYD S. TENNY, *Acting Chief.*
Bureau of Animal Industry	JOHN R. MOHLER, *Chief.*
Bureau of Plant Industry	WILLIAM A. TAYLOR, *Chief.*
Forest Service	W. B. GREELEY, *Chief.*
Bureau of Chemistry	C. A. BROWNE, *Chief.*
Bureau of Soils	MILTON WHITNEY, *Chief.*
Bureau of Entomology	L. O. HOWARD, *Chief.*
Bureau of Biological Survey	E. W. NELSON, *Chief.*
Bureau of Public Roads	THOMAS H. MACDONALD, *Chief.*
Bureau of Home Economics	LOUISE STANLEY, *Chief.*
Bureau of Dairy Industry	C. W. LARSON, *Chief.*
Office of Experiment Stations	E. W. ALLEN, *Chief.*
Office of Cooperative Extension Work	C. B. SMITH, *Chief.*
Library	CLARIBEL R. BARNETT, *Librarian.*
Federal Horticultural Board	C. L. MARLATT, *Chairman.*
Insecticide and Fungicide Board	J. K. HAYWOOD, *Chairman.*
Packers and Stockyards Administration	JOHN T. CAINE III, *in Charge.*
Grain Futures Administration	J. W. T. DUVEL, *in Charge.*

This circular is a contribution from

Bureau of Dairy Industry	C. W. LARSON, *Chief.*
Research Laboratories	L. A. ROGERS, *in Charge.*

ADDITIONAL COPIES
OF THIS PUBLICATION MAY BE PROCURED FROM
THE SUPERINTENDENT OF DOCUMENTS
GOVERNMENT PRINTING OFFICE
WASHINGTON, D. C.
AT
5 CENTS PER COPY